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Space Sociology and Technology

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Space Sociology and Technology

A Major Qualifying Project to be submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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ABSTRACT

This major qualifying project compares three case studies involving space science. The first is a concept of technology 'lost and found' and looks at new technology now in development that may have been passed over for development fifty years ago. The second case study examines a local economic development initiative in Worcester, Massachusetts. Some of the proposed ideas relate directly to space technology and Worcester's potential to be a center for development in the field. The third case study examines the progress and difficulties of a WPI student team participating in a NASA centennial challenge. The combination of these three case studies have implications on a local and national level. Each section contains policy recommendations as to how best take advantage of the growing opportunities.

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INTRODUCTION

This is the story of three half-projects that almost came together. It started out as a locally focused policy question: how, on the 100th anniversary of Dr. Robert Goddard's graduation from WPI, could Worcester take hold of that legacy and get into the space debate?

The idea of an education-oriented mock moon base and a major offered by the Worcester Consortium of Colleges to attract high school aged space enthusiasts and dreamers to Worcester provided the initial stimulus. In the background, we began thinking about the possibility of a special business incubator modeled after the now-defunct NIAC.

Then local inventor Paul Klinkman uncovers a concept for a propulsive fluid accumulator device (ProFAC). This is a national policy question loosely tied to whether he comes to Worcester to develop this device. My job was to get Sterge Demetriades, the initial designer of the concept from the 1950s, a venue to talk here in Worcester. This did not work out, but still provided a fascinating case study.

Then WPI decided to get involved in the NASA Regolith Excavation Challenge – and falters, badly. I am asked to try to consult on the organizational problems and decided I should try to help the leader, a student. The student leader ended up quitting, but I followed the case looking for what to do from a WPI perspective if we wanted to continue to 'play in this league'.

As a result, the policy question is what WPI, Clark and Worcester can do to position themselves jointly and cooperatively to be leading players in the newly emerging space industry, especially if the keys are the school and the space gathering invention, as the start of the incubator.

BACKGROUND TOPICS

Space Policy Climate in the United States

Starting in the second half of the 1950s, the United States aggressively sought access to space. The programs and initiatives experienced varying degrees of success, but many of the earlier designs failed on the launch pad. If not for the government choosing to continuously fund this uphill battle, the space program might –literally– have never left the ground.

When the Soviet Union placed the first man-made satellite in orbit, the world was forever changed. *Sputnik I* was launched on 4 October, 1957, and the 58 cm sphere reached an orbital altitude of 947 km (588 miles). As it circled the globe, *Sputnik* and its booster rocket became the first visible evidence of mankind's egress from Earth's surface. *Sputnik* orbited the Earth for 92 days before its orbit declined, and the amount of data it obtained, though carefully studied, was relatively insignificant; however, it ignited a space fury that changed history (NASA, 2007).

Just two months later, the United States attempted to make the same breakthrough with the Department of the Navy's *Vanguard TV3*. Unfortunately, the rocket failed to launch properly, and the satellite was damaged beyond repair. It took until 1 February 1958 to launch the United States' first satellite, sponsored by the Department of the Army. *Explorer 1* launched to orbit carrying a wide array of simple sensors. One breakthrough discovery it made was the existence of the Van Allen radiation belt. On March 17th of the same year, a second attempt at launching a *Vanguard* satellite was made, and was successful; however, this would be the last fruitful launch from any country that year. Between the United States and the Soviet Union there were seven more attempted launches in 1958, none of which accomplished the intended goal of reaching the moon. The closest attempt, United States' *Pioneer 3,* reached an altitude of nearly 64,000 miles, or a little less than a third of the way to the moon. This phase of both countries' space programs produced the first representation of the cold war arms races in space technology. The competition was so fierce to reach the moon, that the Soviets' *Luna 1958B* and United States' *Pioneer 1* launches were attempted only a few hours apart. Despite these failures, both countries continued to learn from these launches, in addition to challenging one another to achieve loftier goals (NASA, 2007).

1958 saw another important milestone in the formation of the National Aeronautics and Space Administration (NASA). The National Aeronautics and Space Act was signed on 29 July 1958, and it replaced the existing national space authority (the National Aeronautics and Space Council) with NASA, a new civilian body (U.S. Congress, 1958). President Eisenhower recognized the importance of having a single, central, civilian space authority and sent Secretary of Defense Neil Hosler McElroy a memorandum notifying him that he would be giving NASA oversight over existing Department of Defense space projects (Eisenhower, 1958). Centralizing the space efforts in the United States sent a clear message that space flight would no longer be earmarked from the already tight defense budget. NASA would receive its own funding, and would have a mandate to take and hold the lead in the developing space race.

When President John F. Kennedy was inaugurated in 1961, he made it clear that the new administration would not fall behind the Soviet Union in the arms race. In his inaugural address, he stated that, "We dare not tempt them with weakness. For only when our arms are sufficient beyond doubt can we be certain beyond doubt that they will never be employed" (John F. Kennedy Presidential Library & Museum, 1961). This commitment to superiority referred as much to high-technology space developments as it did to actual weapons, as the space program had originally been developed through the military. He clarified his position on space shortly thereafter, in his speech to a joint session of Congress just four months later, on 25 May 1961:

> …this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish (John F. Kennedy Presidential Library & Museum, 1961).

President Kennedy made it clear that the recent successes of the Mercury program, which had placed first a chimpanzee named Ham, then Astronaut Alan B. Shepard, Jr., in space, was proof that NASA was steadily moving in the direction of manned flights to the moon (NASA, 2005).

After the successes of the Mercury program, the next logical step in 1961 was the Gemini program. The Gemini program achieved most of its set goals over its seven flights by 1966. The Gemini program was intended to study specific tasks needed to go to the moon (NASA). First and foremost, the program included increasingly long-term stays in space to improve life support systems and general living conditions. These tests were to be carried out on a two-man crew, doubling the occupancy of the single-seat *Mercury* capsules. Second, it would test the capabilities of docking two spacecraft in orbit, and controlling both with the thrust of one. Third, the reentry procedures were to be perfected. Initially, this included land-landing procedures; however, these tests were cut from the program in 1964. Finally, the program sought to continue to study the physiological effects of space and weightlessness on astronauts. These test flights provided the base knowledge necessary for the final phase the quest for the moon.

NASA had been preparing for the Apollo program as nearly as 1961, when the first *Saturn* rocket was tested; however, it wasn't until 1967 that the first manned Apollo mission was planned. Tragically, Astronauts Virgil "Gus" Grissom, Roger Chaffee and Edward White were killed when a fire burned out of control in the Apollo command module during an engine test. Because of this, manned Apollo flights were suspended immediately. The next Apollo missions were unmanned, and were critical stages in developing the safety and navigational systems aboard the final design of the Saturn-V rocket. Apollo missions 7-10 carried crews of three astronauts and explored increasingly bold components of lunar missions. Finally, after rehearsing every aspect of a lunar mission except landing, Astronauts Neil Armstrong and Edwin "Buzz" Aldrin, Jr. set foot on the moon as part of Apollo 11. 20 July 1969 marked mankind's arrival on the moon, and on 24 July, the crew returned safely to Earth (NASA). The United States had achieved the goal set by President Kennedy to land a man on the moon and bring him home safely; however, this day also held an early climax for the space program- with the goal of going to the moon met, the wholesale support and funding of the space program soon waned, and NASA would have to redefine its mission, and prove its value, to the United States.

After successfully reaching the moon, NASA found that it was without a major challenge around which to organize itself and inspire the people. The final six missions of the Apollo program sought only to extend the knowledge gained on the first lunar excursion, rather than to break new ground or set the stage for a potential lunar base. If not for the Apollo 13 mishap, public attention to the space program may have faded even sooner.

Because of this, President Nixon and NASA Administrator James C. Fletcher met in 1972 to discuss the future of the manned space program. Von Braun had proposed a twenty year program involving a space station, a moon base and a trip to Mars. This was rejected as too ambitious. In an effort to transition from the experimental concepts of the 1960s to a more modern and sustainable design, the reusable space shuttle concept was announced. This would open space up to more Americans on a routine basis, and would solidify NASA's purpose through the 1990s (Roger Launius, 2007).

Simultaneously, NASA began an unmanned campaign of launches to other planets in the solar system. Though they didn't formally announce this as a goal, it seemed logical to consider a manned mission to another planet now that the moon had been reached. As a continuation of the Pioneer program from the early 1960s, these nuclear powered spacecraft sought to reach far off planets and return data that would be critical in considering future launches. Several years later, though before the Pioneer satellites reached their destinations, NASA launched *Viking 1* on a mission to land on Mars. The landing on 20 July 1976 demonstrated NASA's ability to travel to another planet and land safely, and the spacecraft was able to provide a wealth of data for over six years (Roger Launius, 2007).

With the end of the Apollo program and the transition into a shuttle, the Saturn-V rocket design was still of use to NASA. In 1973 the first space station, *Skylab*, was launched atop an unmanned Apollo rocket. This station initially experienced major malfunctions, but was repaired and hosted three different astronaut crews for extended periods of time. This information was crucial in determining the direction of the 'new' space program. The final use of the Saturn-V rocket came in 1975, when the Apollo and Soyuz spacecraft docked in the first ever international space rendezvous (NASA). Although this was touted as a major technical breakthrough, it was much more significant in its policy implications. For the first time since the launch of *Sputnik*, the ever present competition between the United States and the Soviet Union was set aside. This marked a turning point in the space programs of both nations, as they would now be more concerned with success for the sake of scientific progress, rather than to outdo one another.

When it launched the final Apollo rocket in 1975, NASA fully committed itself to the space shuttle program as the next generation of manned space flight. Test flights in the atmosphere throughout the 1970s helped develop major technological breakthroughs that made the orbiter possible. The two main design features were the lifting body design and the fly-by-wire control system. The X-24B was the primary demonstration aircraft that proved a lifting body design could be landed safely without external propulsion. The F-8C aircraft demonstrated that a fly-by-wire control system could operate the flight control surfaces without the mechanical cable backups common to aircraft of the time. By 1977, armed with these and other breakthroughs, NASA began testing the first space shuttle, *Enterprise. Enterprise* proved that the reentry concept would work and, after five flights, became the subject of almost four years of intensive ground-testing. Satisfied that every angle of this new program had been studied, NASA launched the space shuttle *Columbia* into orbit on 12 April 1981. This flight became the first to use both liquid-fueled and solid-fueled rockets to carry a man to space, the first aircraft to land from orbit, and the first reusable spacecraft (Roger Launius, 2007).

At the same time the space shuttle became operable, the climate of satellite launch was changing in the United States. More and more commercial satellites were being designed in anticipation of the launch capabilities of the orbiter. In addition, the type of satellites most commonly designed shifted from scientific research to more practical uses. Through the 1970s the shift toward weather, communications and terrain-mapping satellites was dramatic, and by the time the space shuttle program was in full swing, the United States' private satellite industry was prepared to blossom. President Reagan made a sweeping announcement in January of 1984, setting NASA's sights on a manned space station within a decade (Wade, 1997-2007). This marked the first formal statement of the United States' commitment to what would eventually become the International Space Station.

United States space policy through the 1980s was largely driven by the cold war. An increasing level of presence in orbit by other nations led the United States to fight to remain the top contender in this area. This view has led to a decade of focus on dominance in Earth orbit. Although the 1980s and 1990s saw the results of many earlier launches to other celestial bodies come in, the focus was on launching and maintaining a growing satellite network.

In an effort to match the Soviet Union, NASA had planned to launch a space station similar to *Mir*. As the Soviets developed *Mir 2*, the United States designed the space station *Freedom*. In 1984 President Reagan announced NASA Administrator James M. Beggs' plans to build an orbiting workshop, laboratory and observation point (Wade, 1997-2007). Like all other aspects of NASA planning, this space station was suspended when the space shuttle *Challenger* exploded 73 seconds after launch on 28 January 1986 (Wikimedia Foundation, 2008). The loss of the shuttle and death of the seven astronauts on board led to a moratorium on manned space flight in the United States and significantly increased safety standards. As a direct result of this incident, the cost of manned space flight increased dramatically to account for extra safety precautions and research. Because of this, funding for the *Freedom* space station plan became scarce and in 1987 Congress limited the cost of the project to $12.2 billion (Wade, 1997-2007).

In his "Presidential Directive on National Space Policy" President Reagan outlined what he considered to be the most important components of the space program. The 11 February 1988 document made it clear that the priority of the space program would be to "…strengthen [the] security of the United States…" first and foremost, with scientific research and observation at a lesser importance (Reagan, 1988). President Reagan also discussed encouraging private sector involvement in space, something he thought would be supported by the development of a space station. The directive reaffirmed the country's commitment to peace in space; however, it made it clear that this would not be taken as a sign of weakness:

> The United States is committed to the exploration and use of outer space by all nations for peaceful purposes and for the benefit of all mankind. "Peaceful purposes" allow for activities in pursuit of national security goals (Reagan, 1988).

This directive ensured that NASA and the federal government would align their goals, as well as providing a concrete statement to the rest of the world that the United States would maintain its position in space. The Soviet Union, already struggling, would not be up to President Reagan's proposed pace in development.

While the Soviet Union moved closer and closer to collapse, NASA and Congress struggled to come to terms on the space station project. Eventually cutbacks and revisions led to a diminished space station design that was budgeted for only $6 billion. Called 'Space Station Fred' sarcastically by the press, NASA's final design in 1991 barely resembled the bold space station *Freedom* originally proposed seven years before (Wade, 1997-2007).

When the Soviet Union finally did shatter, it was determined that *Mir 2* and *Freedom* would be combined, along with other efforts, to build the first international space platform. In 1993 NASA announced its full support of the *International Space Station (ISS)* and work began to convert existing designs into modules for the new project. Thus, from 1993 until its projected completion, the United States' space policy goals were to include dedication of the space shuttle fleet to building the *ISS*.

NASA's vision statement in 1996 echoed the sentiments of President Reagan's 1988 directive; however, it lacked the heavy references to the Cold War. Having entered into a period of cooperation with the Russians, and other space-going nations, NASA's focus was more on contemporary issues. In this vision statement, NASA made its self-importance clear by referring to itself as "…an investment in America's future" (NASA, 1996). The objectives remained similar, advancements in technology, exploration, science, communications and travel in space, but the projected outcomes were more directly tied to popular issues: "Economic Growth and Stability..., Preservation of the Environment…, Educational Excellence…, and Peaceful Exploration and Discovery…" were heralded as the four major categorical deliverables (NASA, 1996).

With completion of the *ISS* approaching in the year 2010, need for the space shuttle program is diminishing. Particularly in light of the *Columbia* space shuttle disaster in February of 2004, real concerns are being raised about the continuing reliability of the platform (Wikimedia Foundation, 2008). The loss of the seven crew members on *Columbia* has contributed to a final decision by NASA to discontinue shuttle launches after construction of the station is completed. The next generation vehicle currently in development will be required to meet NASA's new goals.

The new Crew Exploration Vehicle (CEV) is being designed in phases based on NASA mission goals. The first phase will simply replace the space shuttle in ferrying astronauts and cargo to and from orbit. After phase one, the CEV's intended use illustrate NASA's new goals.

Phase two will run similar to the Apollo program and will deliver astronauts to the moon for short periods of time. Phase three will be dedicated to longer-term living on the moon, possibly setting up a base or even a colony. Phases four and five are indicative of NASA’s true intentions. Phase four will act as a planning and rehearsal stage for a mission to Mars, and phase give will be the first manned Mars landing. NASA has promised this will take place sometime soon after the year 2035 (NASA, 2006).

The current space policy climate in the United States is one that pushes outward from Earth orbit. Where two decades ago the focus was on placing a space station in orbit, new politicians and administrators are now struggling to come to agreement on the best way to leave Earth for distant shores. Therefore, the environment for research and development is rich with opportunity for both governmental and private organizations to grow into the expanding market. NASA’s adoption of the CEV program, a return to pre-shuttle technology, indicates that older concepts are not necessarily outdated. As a result, old designs and new techniques are being integrated to produce great advances in technology for the United States and its partner nations in space.

The City of Worcester and its Space Asset, the Students of Worcester Polytechnic Institute

The city of Worcester has long been an unusual part of the Commonwealth of Massachusetts. Originally known as Quinsigamond, the first permanent colonization took place in 1713, with Worcester being formally incorporated as a town in 1722 (Advameg, Inc., 2008). Many years of development through less conventional means than the neighboring city of Boston led to a unique mindset in early Worcester. In fact, when it came time for the 13 original colonies to ratify the U.S. Constitution, voters from Worcester nearly thwarted the whole process over concerns that the new federal system would impose too much on the city. Ratification by the Commonwealth of Massachusetts came within a few votes of failure because of the representatives from the Worcester area (Wallace, 2007).

Worcester's reputation as an industrial center began in 1828 when the Blackstone Canal opened a connection to other nearby industrial cities (Advameg, Inc., 2008). Within twenty years, Worcester grew from a town to a city, and began to spread out geographically. The College of the Holy Cross was founded in 1843, and became the first of many academic institutions in the city. In keeping with Worcester's reputation for unusual behavior, Holy Cross was forced to craftily provided diplomas signed by the president of Georgetown University. This was due to the fact that the college was denied a charter from the Commonwealth of Massachusetts until 1865 (College of the Holy Cross, 1999).

One of many individuals to become attracted to the city of Worcester at an early age was Dr. Robert Goddard. Goddard began his groundbreaking research in rocketry in 1909 at Clark University, and earned his doctorate there in physics in 1911. At the same time, Goddard was conducting research on magnetic forces in a specially designed stone laboratory at nearby Worcester Polytechnic Institute. Goddard went on to impact science locally as a professor and the head of the Physics Department at Clark University as well as globally by inventing liquid fuel for rockets and becoming known as the father of modern rocketry (Bellis, 2008).

Worcester never experienced the growth and expansion that Boston did; however, it did become a center for technological development. As it grew to a booming industrial city, Worcester spawned innovations ranging from the first bicycle to the bazooka weapon (Berka). Recent expansions have seen a medical complex featuring a range of teaching hospital services, various engineering and manufacturing firms and a biomedical center sponsored by Worcester Polytechnic Institute, known as Gateway Park (City of Worcester, MA).

Although many private firms have flourished in Worcester, residential life has not enjoyed the same successes. The city's administrators have continually tried to increase the standard of living by attracting more middle and upper class residents. Initiatives such as the Worcester Common Outlets and CitySquare are just two examples of the many efforts being made by local politicians (City of Worcester, MA, 2007-2008).

Worcester Polytechnic Institute has noted the current trend towards space exploration and has attempted to solidify its reputation in space technology. Worcester's history shows that is people and products have often been essential to the space program, and WPI is anxious to ensure that it does not get passed by in this new era.

Over the last decade it has become clear that the world is in the midst of a new space race. China, the United States, and other space-going nations are about to be locked into a struggle rivaled only by the intensity of the Apollo program of the 1960s. In an effort to grapple with the complexity of such a competition, teams of research students from Worcester Polytechnic Institute have been conducting studies for the past several years.

The first such report contained a Delphi study on 20 ‘breakthrough’ technologies (Flaherty, Monfreeda, & Luca, March 1, 2007). Part of the research was to project which technologies would come to fruition by polling and interviewing experts in the field; however, the more impactful part of this study looked at how much these breakthroughs would affect space travel, if at all. The Atmosphere harvester idea got mixed reviews, from the dephi panel so a WPI team was formed to look into the matter further. This was not the only idea on the instrument to become the focus of a project group’s attention. In the end about 6 would get concentrated attention. Many of these would propose wording changes to the original items once they understand the issues it raised in detail. It became clear that in the future a single team should not try to come up with as many as 20 good items. To make a sufficient study of them for this purpose 4 or 5 would be about the limit of a 2 person team’s ability. However, it was now clear how to upgrade the instrument based on in-house studies and NIAC panel comments (Gillis, Stawasz, & Wu, January 11, 2006). Ironically it would be the Upper Atmosphere harvester idea that would be the idea that emerged as the most promising and the IQP teams looking into it would shift from assessing it and considering its social implication to overtly trying to push the idea, develop it and make it come about. It is even more ironic that one of them would end up doing a revised Delphi study as part of the process of making the idea more credible to potential funders.

Since 1999 over four dozen projects related to space in some way have been completed by WPI students (Johannesen, 2008). This effort is stimulating the emergence of a view of the near future that is interesting to some figures in city government who have begun to wonder how to position the city to take part in the next round of activity in the space program. WPI also has an interest in trying to attract people who want to enter this field. WPI's efforts, running concurrently with Worcester's initiatives, should be enough to create a positive local environment for education, investment and research growth in this area.

The 2008 Regolith Excavation Challenge

The 2008 Regolith Excavation Challenge is an attempt to gather enterprising groups from around the country in a competitive effort to develop new space technology. Regolith is the substance at the surface of a planet. This can include dirt, rock and dust-like particles. When referring to the moon, regolith is used to describe a very fine material that has built up over millennia of meteorite impacts. The surface of the moon is mainly thin dust, but approximately 15% of the regolith is made up of slightly larger fragments called breccias (Korotev, 2007). Because of its unique properties, lunar regolith presents some unique challenges to mechanical devices. Because NASA is currently considering a return to the moon, a robotic device designed to move regolith for excavation and to process it is of particular interest to the agency..

This challenge, which is part of NASA's Centennial Challenges Program, is co-sponsored by the California Space Education and Workforce Institute (CSEWI) and will be jointly hosted by the San Luis Obispo College of Engineering at California Polytechnic State University, and the California Space Authority (CSA) (CSEWI, 2007). In early August the competing teams will meet for head-to-head competition to determine which autonomous robot can move the most simulated lunar regolith to the designated place in the thirty minute time period allotted. Restrictions have been placed on size and weight of the robotic devices, as well as how they operate within the 'sandbox' judging area. In addition, the teams will only have access to 150 watts of electrical power. All of these restrictions are designed to simulate the limitations placed on design teams that are forced to consider the cost of launching cargo to the moon, as well as the small amount of electrical power available via battery or solar sources (CSEWI, 2007).

Because the challenge takes place on Earth, it is impossible for teams to focus on building a ‘moon-worthy’ robot; however, the concepts they are tasked with developing should translate fairly directly into different approaches to the ask at hand and stimulate the thinking of those actually assigned to design future devices destined for use on the moon and elsewhere If the United States, or other nations, plan to build any kind of structure on the moon, they will need to move substantial amounts of regolith. Since flying large construction vehicles and crews to operate them on the moon is prohibitive or impossible, light but capable robots will be needed,

In 2007 the first Regolith Excavation Challenge was held. The sponsors, location and parameters were the same as 2008, but the devices did not have to be robotic and the purse offered was significantly less at $250,000. Four teams entered, each fielded by a private organization rather than an academic program. The competition lasted only a day and was open to the general public (CSEWI, Spring 2007).

When it came time to actually run the competition, only one of the four devices functioned properly, and none moved the minimum amount of simulated regolith to win. The other three experienced casualties due to mechanical and electrical problems. Though disappointing for those involved, this was actually useful information. The complexity of the challenge made it clear why this problem was so difficult when considering an actual moon mission. The one robot that did operate, from the Technology Ranch group out of Pisno, California, performed reasonably well, and was able to move 62.5 kilograms of regolith material (CSEWI, Spring 2007). This fell short of the required 150 kilograms, so the team did not earn the prize; however, it was provided NASA with enough proof of concept that the contest was reopened in 2008 with the larger prize purse, more power available and stricter rules about autonomous operation.

The contest did not yield a robot that was up to the standards set by NASA, CSEWI and CSA, but was still an overall success. The fact that the number of entries into the contest increased 500% from 2007 to 2008 clearly indicates a level of interest that is seriously dedicated to accomplishing the goal (CSEWI, 2007).

The 2008 Regolith Excavation Challenge has attracted a wide variety of serious competitors. The $750,000 prize, coupled with the publicity surrounding the event, has appeal to all sorts of organizations. Schools, businesses, and even individuals have posted the $2000 entry fee and it is very likely that more than one group will meet this year's minimum standards (CSEWI, 2007).

The University of British Columbia has sponsored one of 2008's promising contenders. In April, 2008, UBC's TREAD Robotics team announced that it had reached the 1000 man-hour mark, and was entering a critical test phase. According to the group's biography on the challenge's official website, the group was founded by "a few like-minded friends in October 2007," and has since grown to be a fully supported UBC organization. The team has made an effort to recruit the best engineers with a range of skills to ensure that their design is sound. The group is made up of representatives from four engineering departments as well as the Computer Science department. The team's philosophy on the contest sums up the common theme for all the teams:

> The NASA Regolith Excavation Challenge is a unique opportunity for engineers and computer scientists with interests in robotics … to corroborate on a project of truly

enormous scale… designing, prototyping and building a prize-winning excavator (CSEWI, 2007).

After making a promising showing in 2007, the team from Technology Ranch has promised to provide an even better robot for 2008. This group makes it clear that it intends to win the contest, publicly stating, "This event offers a significant challenge to all participating teams, and [the Technology Ranch team] wishes them all great success in taking the second and third place positions" (CSEWI, 2007). This type of competitive spirit is precisely what the sponsoring organizations hoped to inspire and it may lead to impressive performances.

Most of the twenty competing groups are, like UBC Tread and Technology Ranch, a business or school team; however, one group has a more 'homey' feel to it. Hudson, Wisconsin's Green Cheese Solutions team is made up of a husband and wife working out of their home basement. The couple learned of the competition from a magazine article and decided the contest was unusual enough that even a team with limited resources should be able to find success. Both have engineering backgrounds, and their unusual circumstances may provide a spirit of innovation not found in other designs (CSEWI, 2007).

Though the teams all have varying inspirations and backgrounds, they all share a common idea that the challenge minimum requirements can be met. The question is which device will be the best one, since it is now a matter of relative rather than absolute success. The ability to review the performances of 2007, and the commitment of hundreds of experts nationwide, means that there will likely be twenty ground-breaking designs. Regardless of whether or not the challenge is won, NASA will have many new designs to consider when tackling the problems involved in moon construction and process local resources to meet the other needs of the lunar base, especially mining oxygen. The entry fees for the contest should have been high enough to eliminate any team not serious about competing, and the lessons learned in 2007 will likely mean that there is a realistic understanding of the difficulties in this contest. August of 2008 may see the proof of one of the more important design concepts involved in NASA's return to the moon.

TECHNOLOGY LOST AND FOUND

Introduction to the Original Propulsive Fluid Accumulator

The ability to refuel spacecraft in orbit from local resources is one that will open more doors than perhaps any other likely breakthrough between now and 2050. After that there may be a space elevator that provides truly cheap access to space. Short of that, providing the heaviest ingredient in rocket fuel means that the cost of satellite maintenance and space travel could drop significantly. In addition, the Earth's surface would no longer be the only 'launch platform' for long-range space flights. The current problem with orbital refueling is that to carry enough fuel into orbit to refuel one spacecraft would take 15-20 normal launches from the ground. At the moment, 90-95% of fuel is burned just to reach Earth orbit.

The first attempt to solve this problem took place in 1958, during the era of such space pioneers as Dr. Werner Von Braun. Sterge Demetriades was a young Northrop-Grumman engineer who had developed this idea while in grad school but left to head up a related feasibility assessment project with government funding in industry. He claims that his team brainstormed this idea to the point of making four related inventions for refueling in orbit, though not all of them are in the open literature. Demetriades had an A.B. in Physics, Math and Chemistry from Bowdoin College, a degree in Mechanical Engineering from California Institute of Technology, and a M.S. in Chemical Engineering from Massachusetts Institute of Technology. After his stint with Northrop-Grumman and involvement in the U.S. space program, Demetriades would go on to enjoy considerable success as an entrepreneur in the computer-related science and technology fields, founding several thriving corporations and serving in various roles from CEO to Board of Directors. He would later become interested in energy research.

The design Demetriades developed in 1958 was a concept for a propulsive fluid accumulator (ProFAC) using cutting-edge technology of the time. The device was powered by a small 10 mW nuclear reactor, which provided electricity to the mechanical systems onboard. Demetriades projected that the device would orbit the Earth at 75 miles in altitude, skimming through an area of thinner air. The design was intended to 'scoop' air out of the atmosphere using a combination of technologies. The primary means of collection was comprised of mechanical compressors, a technology which was well-established in jet engines by this time. In addition, Demetriades felt that the incredibly high speed of orbit (over 17,000mph) would require a more complex method of collection. For this he elected to use a ramjet, which is a jet engine that has no moving parts. The major requirement of a ramjet – fast movement through the atmosphere – was inherent in the operation of Demetriades' design. Ramjet technology was just being developed at that time, so this added greatly to the complexity and cost of the design, but it was relatively elegant in principle.

At the altitude ProFAC was designed for the atmosphere is made up mostly of nitrogen. Rather than bleed off this 'waste gas', Demetriades hypothesized that a nitrogen/oxygen mix could provide a highly efficient liquid rocket fuel but his plan was to superheat it , hence the nuclear reactor. Due to its high weight to volume ratio, most of the storage space on ProFAC was devoted to storage of compressed and liquefied air. Despite its complexity as a spacecraft, the navigation and docking systems on ProFAC make up only a small portion of the systems.

Although some people at NASA seem to have been intrigued by the concept, the NASA administration at the time did not feel as though this project was needed to achieve the goals of the U.S. space initiative at the time. Sterge himself said that it was designed to be part of an infrastructure to support regular trips to the moon, not just a few. Hence, it was worth the investment to maintain a facility on the moon, rather than just visit it. Projections at the time suggested that the device could be sufficient to fuel a monthly launch from Earth orbit to the moon. NASA's stated mission until 1969 was to fly a man to the moon, then safely return him to Earth. There were no explicit provisions for continued presence on the lunar surface, so concerns for an efficient means of fueling these missions was not anyone's job at the time. There was also no space station to supply, though Von Braun would propose both a space station and a moon base as part of a 20 year program leading to a trip to mars for the post Apollo era. This plan was not approved by the Nixon administration.

The only thing that was later approved was the building of a shuttle craft to LEO, so the US was not going to retain the capability of going to the moon, though no one knew that in 1958. The small number of approved moon trips at that time meant that ProFAC would not even be economically feasible, particularly due to its high initial cost. NASA decided not to develop the idea at the time.

After being turned down by NASA in 1958, Demetriades' ProFAC design was published in the BIS *Journal* where it received the attention of some top minds in the aerospace field. The design was peer-reviewed by Ernst Stuhlinger, Von Braun's Chief Science officer at the Huntsville Space flight Center. His review makes it clear that he felt if one had a nuclear reactor on board anyway, a nuclear drive might be the way of he future. He was not sure using this approach had any economic advantages over directly powering the craft with the reactor.

Significantly, he did not say that it would not work. In fact, a nuclear drive does need to superheat and eject something and many people presumed at the time that that would be water. Given the cost of taking that to orbit there actually is a very good economic reason to liquefy air in orbit and eject that instead: you do not have to carry that from Earth.

In any case, for whatever reason, it was not considered necessary at the time to plan for the post Apollo Era and bring down the cost of operating in space. Candidly, it seems to have been considered the answer to a problem they did not yet have and there was no reason to believe that this concept could not be developed later to be part of chemical or nuclear drive system if needed. In 1959, amidst some academic interest in the plan, and the real possibility that Northrup might try to sell the idea to a user other than the US government, and thus bring attention to it, the U.S. Air Force classified it to prevent publication in the open literature of Sterge's 4 detailed reports done at Northrup with US government funding.. Though the concept was not usable at the time, the Air Force considered it interesting enough to set aside for future development, while simultaneously keeping it out of the hands of the Soviet Union which had a lead in the space race in 1958.

Losses and Opportunities

Based on calculations involved in the initial design proposal in the 1950s and 1960s, along with contemporary studies done with updated numbers, the losses associated with not developing ProFAC during the 1960's and using it to continue the space program afterward at an affordable price are astounding. In areas ranging from consumer products to high-technology science experiments, ProFAC could have provided a much more cost-effective way to operate in space.

Today, the cost of carrying a single pound of cargo into orbit using the Shuttle, (other countries have cheaper ELV's that cost about two thirds as much) is around $10,000. Carrying fuel for satellites and spacecraft takes up a considerable portion of the cargo capacity on U.S. space shuttles, and thus limits the period in which they can operate in space. When the task is to be a space trick engaged in building the International Space Station (ISS) the less you can carry per trip the slower the progress and the more trips necessary to complete the task. . Furthermore, 70% of the space cargo launch market was lost by the USA to the Arianespace organization marketing ESA's Ariane launch sustem. The Russians and Chinese had most of the rest of this market

The US shuttle was not competitive with these heavy lift ELV systems and could not become so unless it could stay in space longer and do more on each mission. In short, it had to be able to refuel and be combined with an ELV program, such as the Delta rocket to send things up to a shuttle already in orbit to deploy, repair, upgrade and all the other things done on Shuttle missions, only some of which involve building the space station. NASA phased out the Delta program to build the reusable Shuttle, and later, after the shuttle Challenger was lost and the shuttle fleet grounded, US industry, especially Lockheed, was encouraged to start building and developing the Delta family of launchers again However, US industry was not able to take back the commercial launch market from foreign competition without government subsidy. These companies live off of US government, mostly military contracts. Using ProFAC, or a similar concept, NASA could potentially be sending 15 tons of cargo to the moon for less than the cost of a single space shuttle launch. Another study has calculated that the cost to place a pound of cargo on the moon could have been as low as $54- it which point building a moon base is cheaper and easier than building a space station. The bottom line estimate, as it would apply to today's technology, is that there would be much less junk in space and the cost of operations in space would be much lower than it currently is if satellites were designed to be refueled. Since the US did not develop this capability using local resources already in space , it was not worth it to take fuel from earth just to refuel them. It was easier and more reliable to just replace them. If satellites could be refueled their design life would at least double and the cost of operation per year in service would be about 10% of what it is now. They would be designed differently and be much more durable, if they were designed around a ProFAC capability.

The tangible opportunity cost of not taking advantage of this breakthrough five decades ago is impressive. Space science could be a much wider field, making use of freed up cargo area on launches to lift satellites, scientists, and testing equipment. From a national defense standpoint, the United States could have saved significant sums of money during the Cold War and since on observation and communication satellites that had to be replaced when they ran out of fuel and could not be moved to new orbit and locations for lack of fuel. A nearly complete reliance on satellite technology for communications, surveillance, navigation, and potentially for weapons, places the U.S. Department of Defense near the top of the list of groups which might have benefitted from this technology had it not been lost and forgotten when it was classified. The U.S. Air Force once considered building its own fleet of shuttles, but decided instead to buld big ELV's such as the Atlas and Titan. A launch cost about the same but more mass could be launched in each mission. Given these big dumb rockets for brute lift, the US could have had the best of both worlds. With a space station, a shuttle fleet and heavy lift the only thing missing was refueling capability to keep the fragile shuttle from having to go up and down so much. It could have operated out of the space station for 6 months at a time with two crew rotations using the 3 man Soyuz to bring up replacement crew members. Oncethe shuttle could be refuled and the Space station did not need fuel brought from Earth to reboost and stay on station, all one needs to do is be able to lift mission related equipment in big loads from Earth and the Shuttle just gets resupplied and refueled every 2 weeks and sent on a new mission moving things around in space and doing servicing and refueling missions. Orbiters that are not going up or coming down on rarely at risk, so the Columbia and Challenger disaster might have been avoided, especially Columbis since repair and refueling would have been a standard capability and the los of heat shield tiles would have been noted and repaired before the Columbia was allowed to return to Earth. It could still have operated in space indefinitely even if the problem was not repairable and it could never be returned to Earth. The savings in cost and safety of operations in space might have changed the face of the global economy.

Governments would not be the only groups to benefit from this technology. In the last ten years there has been a surge in satellite-based consumer electronics. In 2007 the Automotive Business Review estimated that 7% of cars on the road in the United States were operating a global positioning system (GPS), which utilized satellites to navigate along public and private roadways. In addition, the satellite radio industry anticipates an estimated growth from a fledgling 4 million subscribers in 2005 to around 35 million by 2010. This service is providing listeners with a variety of audio entertainment options and is available continuously in places that traditional AM/FM radio broadcasts cannot reach. Given that these industries have thrived recently, even in an expensive operating environment, it is reasonable to assume that these and other private industries could have experienced an accelerated development. Relatively inexpensive access to orbital capabilities could have caused an early boom in the technology market.

Gaining access to a fuel supply in space would have boosted the U.S. economy in multiple arenas. In addition to the direct benefits to domestic industry and governmental agencies, there is a hard to estimate aspect of the advantage of controlling access to a fuel supply in orbit. Having the option of distributing fuel to other nations would have given the U.S. political and economic power in space that has not yet been realized by any space-going nation.

Fast forward five decades: Paul Klinkman, influenced by current global space initiatives and inspired by the question being asked in the delphi research of WPI students, presents a similar concept to a team of WPI IQP students to evaluate, and they can't find a reason that it would not work. Encouraged, he risks a presentation at the annual AIAA meeting. From this he gains some important feedback on the behavior of rapidly traveling oxygen ions and, most importantly, meets someone who knows Sterge Demetriades., who gets in contact with John Wilkes, his co-author. Though Klinkman had found a reference to ProFAC on line and decided that this was somewhat similar to his idea, until this point he was unable to get any useful information on the prior proposal. From this direct contact he gets a citation and learned about the key differences in the two designs, namely differences in altitudes of operation and propulsion systems. With this feedback, the second Klinkman design team has the opportunity to make use of tested and peer-reviewed concepts and the concept gains credibility. He decides that a prototype system for testing could be launched within a few years with funding in the range of a half million dollars and permission to attach something to the outside of the ISS. NASA has a two step program for helping launch business to develop technology. The first STTR grant is typically about $100,000 and one is the eligible to try for a $500,000 grant if the first grant is used well.

This technology is now at a point where, if it is developed, the US could take advantage of great opportunities that it missed out on by passing up ProFAC at the time of the Apollo program. The possibility of leading the world in space travel and space cargo is something that the country cannot afford to ignore, as it did in the 1959 when ProFAC was first declined. This situation is directly analogous to the development of the airplane. Had the Wright Brothers not designed an early wind tunnel, it is projected that this breakthrough of heavier than air flight could have taken another fifty years to come to fruition at the rate things were going. Considering the developments made in the first fifty years of flight (the ‘jet age’, air travel, etc.), the possibilities that could have been realized had orbital refueling been harnessed in the 1960s are endless. This technology was lost, and is now is found, just at thetime we are talkingabout needing regular access to a Moon base. It could be the harbinger of a new era of space flight-but only if, this time, it is utilized.

Policy Recommendation

The way NASA reviews new designs is heavily biased towards credentials rather than towards innovative new ideas and processes. This process has had its successes; however, it can also stifle or ignore brilliant ideas devised by unknowns, outsiders and marginals to the field of credentialed experts. The problem is that the big discoveries and breakthroughs are typically instigated by marginals. The DNA structure was discovered by ornithologist (bird watcher) Watson and physicist (Crick). Field switchers, the young and the outsiders who are not wedded to the prevailing paradigm generally are involved in changing the way a field looks at its subject and the problems under investigation. The case of the Liquid Oxygen in Low-Earth Orbit (LOX in LEO) gatherer being developed by Paul Klinkman is a perfect example. Klinkman's degree is in Computer science but he is an inventor with broad interests who has recently focused on solar power but has a long standing interest in space. He and a sociologist working with undergraduate engineering students who are no aerospace majors developed this concept. Actaully they rediscovered, it but did not know of ProFAC when they began to write their paper for the AIAA meeting. It is very similar to the ProFAC design of the 1950s and 1960s; however, it uses a bold new approach and cutting-edge technology to stay in orbit since now the idea of using nuclear reactors in LEO is considered too risky. This concept is still considered too risky for mainstream consideration. Without the backing of well-known names in the field of aerospace technology, it can't be considered for funding, but the fact that this is the second time the idea has been proposed seems likely to make those in the field take it more seriously than if it had never occurred to someone with credentials working in the field.

NASA currently accepts applications for startup grants for new space technology companies. The initial grants offered are usually $100,000, with another $500,000 available after several years and a proof of concept. The initial startup grant is very difficult to come by and involves a lengthy application process and design review. NASA is looking to outsource the development of new technology; however, they are unwilling to invest in what they consider to be a high-risk venture. This used to be the special mission of NIAC, which had a $6-9 million annual budget. However, NIAC was not refunded this year and went out of operation after a 9 year run. Now it is not clearwhere to take a big idea outside of the prevailing paradigm for serious consideration. This presents a conundrum in that most of the scientists NASA considers to be credible are beyond requesting startup grants. On the other hand, many professional inventors like Paul Klinkman lack even formal postgraduate education, so their contacts and reputations in the field they are entering are usually limited. Hence it is not easy to partner with a credible expert in the field. First you have to get their attention.

If small operations working on ideas like the LOX in LEO concept are to take hold, funding and resources, at least initially, will have to come from sources other than NASA. One possibility is a local collaboration of resources. This collaboration would have to include local government, academic institutions, and possibly even philanthropists or private investors. Resources not conventionally available could be provided in creative ways to afford the developing company with what is needed to grow. An incubator such as this would be beneficial not only to the startup business, but to all partner organizations as well.

The contributions provided by a city government would almost certainly be material but might be “in kind” in nature (tax breaks, a vacant building). In this situation, Worcester might be able to provide more material support to Paul Klinkman than NASA’s $100,000 grant would be capable of providing For example, Klinkman's organization would require space to work, equipment, and utilities. The city of Worcester is in a position to provide these services for significantly less cost to the taxpayer than their dollar value. This tradeoff would benefit the city by attracting new businesses and employees to the area. A contract might be signed, agreeing to keep the startup company in Worcester for a certain period of time after the incubation phase is over. Eventually, growth in tax revenues from young organizations expanding out of this program would provide the financing for its existence.

Even given material support, a startup business cannot function without a workforce. Academic institutions often located in urban areas can provide a diverse group of workers for little or no wages. Worcester Polytechnic Institute would be the ideal institution to provide technically skilled employees for a startup engineering firm such as the LOX in LEO gatherer concept. Engineering Schools already have students working on capstone design projects, and WPI's curriculum actually places seniors in their field for in-depth work on a Major Qualifying Project (MQP). Assigning MQP students to work in a local business incubator on a project such as Klinkman's would incredibly beneficial to all parties. The students (who come with an expert advisor) would have an opportunity to learn about cutting-edge research and development techniques, while getting in at the ground level of a new company. This could potentially lead to future employment once the corporation becomes stable, or would, at a minimum, provide meaningful on-the-job experience in an engineering position. The benefits to the startup would be obvious- utilizing a salary-free workforce trained on the newest engineering techniques and equipment would be the best way to get off the ground. Furthermore, utilizing the projects program at WPI would allow inventors like Paul Klinkman to carefully select students with particular skill sets to complement their own. Finally, the benefit to the academic institution would be enormous. WPI has a reputation a one of the top engineering schools in the country and prides itself on project work done around the world. As the United States ramps up its presence in space, there could be no better way for WPI to expand its reputation than to be involved in a project heading for orbit that could change the economics of space travel.

Once the startup firm begins to move past the research and development phase, it will need additional workers in other fields. Nearby liberal arts school Clark University could provide students, working for credit, specializing in economics, psychology, management, or any number of other critical components to a new company. Clark's relationship to Dr. Robert Goddard would encourage them to become involved with a space startup business, especially considering the centennial anniversary of Dr. Goddard's attendance at Clark is only a few years away. Given Dr. Goddard's tenure as head of Clark's Physics Department, it is even possible that some physicists from the university might be able to contribute to the incubating business.

If less specialized work becomes needed, Worcester's public high schools could easily provide labor from vocational education centers. Since Worcester would prefer to keep jobs and employees local, there would be a large benefit to training high school students to perform tasks in a technology-oriented startup business. These students could supplement the technically trained workers from WPI or Clark and help with the day-to-day administration of the startup.

As the startup begins to take hold, entrepreneurs like Paul Klinkman would eventually need to take full control of the business. Once a concept could be proven, the business might need to begin paying rent or perhaps move out of the incubator. This does not eliminate the possibility of students from local academic centers, but it is likely that the original wave of students would be graduating and in the market for a traditional employment. Transitioning to a self-sustaining business might take a few years, but as the city/school collaboration removes the 'training wheels' the startup might be able to develop an innovative concept that otherwise might never have seen the light of day.

At this point the incubation process will have come full circle. Utilizing the resources of a city and the reputation of a consortium of academic institutions, the startup business would likely have a feasible design with enough credibility to pitch successfully to NASA. This would, in turn, lead to research grants and possibly development contracts. Without the use of this incubation process, NASA might not otherwise ever take the same concept seriously. The people that kept it alive then benefit with development and production contracts based on being the leaders in the field.

This collaboration policy would be ideal for existing startups such as the LOX in LEO gatherer, but would also work for many other space technology firms in Worcester and elsewhere. By pooling resources already available it is possible to provide the credibility and research sought by NASA from those unable to produce it on their own. Of course WPI and Worcester also wants to compete for the contracts on things that NASA does know it wants, things like the regolith excavation system. Having WPI compete in that and win could bring glory back to the school, but also a winning team could decide to spay together and develop a system that could really operate under lunar conditions. They could be housed in the incubator as well.

LOCAL SPACE INITIATIVE

Worcester's Economics, Politics and Education

The city of Worcester is currently undergoing a series of efforts to bolster the local economy. The city's website features exciting phrases such as "The City on the Move," and "Right PLACE, Right TIME" . Worcester promises of economic growth are enthusiastic and optimistic. As the national economy edges closer to the possibility of a recession, this may be a bit ambitious; however, the potential exists for large growth in the next decade if Worcester is able to take advantage of some local advantages.

One such opportunity is the redevelopment of the North Main Street area of the city. Because of recent moves of the city's courthouse to a new facility, several major buildings in Lincoln Square are now dormant. In addition, traffic patterns and zoning constraints have left several parcels of land up for development.

Politically, Worcester's space initiative is a difficult topic to support. Because the focus is so heavy on urban redevelopment, it is difficult for anyone in the city government to support what might be viewed as extra programs. The concept of space science and industry and the lunar economy are so foreign to many of the local politicians that it is not even worth discussing with them.

The most common reaction from both local policy makers, as well as concerned citizens, is that it would be nice to support a space initiative, but it is too far down on the priority list to be of any real importance. Many of them show more interest when they are reminded of Dr. Robert

Goddard's importance to rocketry, and of his background as it connects with Worcester's universities. The reason the concept fails to get beyond this portion of the conversation is that people typically fail to see the potential connection between space technology as a new emerging industrial sector and Worcester's redevelopment.

The popular political trends in Worcester involve pumping money into social programs that show an immediate and obvious return to the taxpayers. Because a space initiative would do neither of these, it requires a very difficult sell to the people of Worcester. Elected officials genrally consider this type of a proposal to be politically unwise, but Worcester has a professional City Manager. Therefore the way this initiative might meet success is to be spearheaded by part of the city's permanent bureaucracy in partnership with the professionals in its school system who would be monitoring the changing mix of jobs in the economy.

North Main Economic Development Strategy

According to Wikipedia, a charrette is "an intense period of design activity" during which people work to solve a "design problem" (Wikipedia, 2007). More specifically, a charrette can be a meeting or series of meetings designed to develop a new and creative approach to a problem. Charrettes can last anywhere from an afternoon to a week or more, and are typically made up of a wide range of participants representing technical experts, policy analysts and concerned citizens alike. Charrettes usually involve a large group breaking down into smaller groups, then reforming to discuss the fruits of the small-group brainstorming sessions. This allows innovative ideas to be broached and discussed at an intimate level, and to then be presented as fodder for discussion by a larger demographic. Charrettes have proven to be ideal in many situations including governmental reform, engineering and architecture.

The Worcester North Main Economic Development Strategy Charrette was designed with the goal of finding the best way to utilize the resources in the Lincoln Square area of the City of Worcester, Massachusetts. The tagline for the charrette is indicative of the desire to involve experts as well as lay-persons:

> On September 29th, the City of Worcester will be hosting a day-long charrette that will explore the issues and opportunities within the North Main Area of Worcester. The agenda will include a series of presentations and "breakout" sessions so that we can share ideas about what changes should happen in the near and long term. Your input is very important to this process and we look forward to seeing you on the 29th! (City of Worcester, Massachusetts, 2007)

This charrette was advertised throughout the city and was endorsed heavily by city officials. Mayor Lukes as well as many city council members and representatives from other governing bodies were present. The whole event was coordinated by the Worcester Economic Development Office in conjunction with Vanasse, Hangen Brustlin, Inc., a nationally known development consulting firm based out of Watertown, MA (Vanasse, Hangen Brustlin, Inc., 2007).

A continental breakfast was served to the participants of the charrette, allowing for a frenzied period of time filled with lobbying, persuasion, and outright propaganda. Many of the local politicians were there touting bumper stickers and pins and, as always, attempting to rally support for their next elections. In addition, several groups of participants had come to the event prepared to push specific agendas. Neighborhood associations in the immediate area such as EHANA discreetly passed out literature to those who were interested and started planting its concepts with hope of pushing through a business incubator in the former vocational school or the former Boys' Club. Taking a different tack, students from WPI provided outlines to one another in order to ensure that the various representatives would be advocating the same agendas in each of the five breakout groups. Regardless of the strategies, everyone with a stake in the North Main area was networking and lobbying throughout the breakfast session, and it allowed for some very important contacts to be made.

The introductory briefing that was given to participants beforehand was not terribly useful for the breakout sessions. So much information was conveyed that it all ran together. In addition, without seeing some specific guidelines from the facilitators of the charrette, it was difficult to understand how information on traffic flow, parcel cost and other similar issues, would apply to the breakout sessions.

The first breakout session was awkward at first because the individuals in the group were not yet comfortable with one another. Each person got a chance to tell everyone their name and priorities, and the discussion began. At first it was not very productive, as everyone was being careful not to offend anyone else, but one member in particular seemed to have trouble being polite, which broke the ice enough to get the meeting flowing properly. Her lack of consideration would prove to be problematic later, but at this juncture it was helpful in starting off good discourse.

Many topics came up, but the prominent ones were Worcester's youth and Worcester's college population. It seemed that everyone agreed that a central location for the gathering of students from the Consortium of Worcester Colleges would be positive for the city in terms of popularity among current students and an attractive draw to prospective students. The topic of Worcester's youth came up from a representative from a low-income housing unit near the North Main Street area that is home to 700+ teenaged or younger children. Her concern was that there was nothing for these children to do after school or in the evenings which was leading to their getting into trouble. Her complaints were that the nearest Boys and Girls Club is too far away for effective use and that the other activities in the area are too difficult to access. Some lesser topics that the group was interested in pursuing included a business incubator and a community center or cafeteria with private restaurant stalls. The business incubator concept was well-received but the group didn't feel as though the old Boys' Club was the best location for such a venture. The group did like the idea of a place where the community could eat as part of the redevelopment plan but wondered about the success of something like that in the North Main area.

After the first breakout session the participants regrouped in the main sanctuary for presentations on findings from each breakout group. The five groups largely presented the same concepts, with the occasional different idea arising briefly. The overall impression was that the groups were willing to consider some fairly unorthodox, even radical, ideas for the development of Lincoln Square and the surrounding area. Ideas included an air and space museum, a collaborative law school in the old courthouse, a food court for local citizens, an activity center for Worcester's youth, an elderly center and a condominium complex. Most importantly to the representatives from WPI, this group presentation yielded suggestions of a common college student center in the auditorium, a business incubator in the former Boys' Club, and a full-scale mockup of a lunar base, to be located in the Lincoln Square tunnel. Getting these ideas across was a crucial step for WPI's teams and the meeting was the first time all three ideas had been heard in a single public forum. Unfortunately, the fifth group presenter was the same rude woman who got things moving in the beginning of the break out session, and she disregarded the group's wishes in order to push her own, unrelated, weak agenda. Because of this, the fifth group was unable to reemphasize the importance of the three concepts being supported by WPI students. Regardless, the regrouping presentations following the first break out session was a positive collaboration with a free flow of ideas.

Following the regrouping presentations there was a lecture delivered by Mr. William Wallace of the Worcester Historical Society. His talk covered the history of the Worcester area, particularly the area around Lincoln Square and North Main Street. This lecture was interesting and educational, but it was also helpful in providing some perspective to the break out session groups in considering that past groups had tackled the same problems being faced by the charrette. The talk ranged from the founding of the city through present-day initiatives. Putting some of the buildings being considered into their respective historical perspectives was very helpful in decided where priorities would lie. It was also helpful in preventing groups from giving buildings a new purpose that would not suit their dignity.

The second break out session was initially more fluid since the group members were already comfortable with one another, but this lead to other problems as the groups sought to decide which specific items and areas they wanted to focus on. Group five immediately had even more problems with the same participant from before, and her rude behavior grew to a point where she was actually asked to excuse herself from the session. The group continued to discuss, in detail, plans for the facilities in the area. It was determined that the most effective place to put a college consortium community facility would be the former Boys' Club. It was determined that this would be more economical than using the auditorium, but that once this facility was up and running it would be possible to expand certain activities into the auditorium. It was also suggested that the auditorium's unique layout would lend itself naturally to a stall-based food court for local patrons and students alike. In addition, the parking lot across the street from the Worcester Palladium was selected as a parcel that would be ideal for development. This development, whether it be a shopping facility or eating establishment, would create a draw that would hopefully encourage foot traffic between the emerging 'city square' development and the North Main area. To further facilitate this, the group also recommended a trolley route that would run on short intervals, allowing patrons to get on and off so they might conveniently frequent the businesses on Main Street. Unfortunately, the group was not willing to commit resources to an underground mock lunar base right away; however, it was not ruled out as an option for the future.

The large group session following the second break out meetings was the same format as the first. The majority of the ideas presented by the groups were similar to one another and did not include much by way of innovation. A common trend was that the more radical ideas that had surfaced in the beginning had been replaced by more conservative and “realistic” approaches. The concept of using the tunnel for any kind of exhibition was largely gone, and the auditorium did not garner much support in favor of reopening. The groups seemed to focus on what could be done fastest and most economically. Following the briefs from each of the five groups, participants were issued three dot stickers with which to cast votes on their priority areas. This was the final opportunity for people to push for their agendas to gain momentum. The interesting thing was that there were so many similar suggestions that it was impossible to tell which idea was taking the lead. This meant that no one in the voting process knew where the high vote concentrations lay. The plan, as explained to the participants, was to have VHB analyze the results and develop a report with recommendations to be given to the city.

The Worcester Charrette was a useful tool to bring solutions to light for a complex problem. It allowed citizens to work side by side with lawmakers and ensured that each person had an equal opportunity to present new concepts. Unfortunately, since it took place over such a short period of time, there was a lot of pressure to “get something done quickly” which caused the most interesting and innovative ideas to get pushed aside.

Policy Recommendation

The City of Worcester is at a critical juncture in its history. Modern technology allows workers to live farther and farther from their place of employ, leaving cities like Worcester struggling to attract residents based more on merit than on necessity. Now, more than ever, decisions regarding entertainment, safety, education and general quality of life will have a direct effect on the population dynamics of the city. Attracting more middle class residents, and retaining those that currently live in the area, will increase the tax revenues for the city. As this economic growth cycle proceeds the opportunities for the lower class to progress into the middle class will expand as well, allowing even more growth in the future.

The charrette produced many viable options for the city of Worcester to consider. The Office of Economic Development showed particular interest some ideas, while other city departments became more involved after the fact. Ideas ranged from trolley routes to museums to a pavilion similar to the food court setting in Boston’s Fanueil Hall. Some pragmatists were more interested in building parking lots to encourage a laissez-faire approach to economic growth along Main Street. The group that provided these ideas was made up of average Worcester residents, although the fact that they volunteered to give up a Saturday to participate may suggest a certain selection bias; however, the fact that the groups were randomly assigned and produced team concepts counteracts this.

Several months after the charrette, the Worcester school committee expressed serious interest in the idea of a simulated moon base and business incubator. Since some members of the committee already have outside ties to local universities, a new partnership would not be out of the question. The properties surrounding Lincoln Square have the potential to be adapted for use in such a project and are already owned by the city. A simulated moon base could be designed, built and run by students from WPI and Clark University as both schools have historic ties to the space program. Sponsorship could come from local and national high-tech firms as well as from NASA's youth outreach programs and would likely be in the form of material support or educational material. A business incubator in the same facility would bolster the statement that the city of Worcester welcomes the space industry with open arms. Startup businesses are frequently searching for such an opportunity, and the workforce could be easily supplied by local schools in exchange for relevant course credit.

Implementing this concept would be a major benefit to the city of Worcester. The site would be a frequent destination for school field trips, improving the curriculum options in the education system. Businesses would be attracted to the incubator, either applying for the program, or looking to work with the growing businesses being produced. The Lincoln Square area would be improved as one of the currently unoccupied buildings would have tenants. Bringing that part of the city back to life might inspire more commercial and residential growth in the area, satisfying the city's original goals in the North Main Economic Development Program.

If the colleges also collaborated on an integrated space studies major and minor that one could take along with any other technical, business or humanities major, one would not only have identified the students and academic unit to run the moonbase, but would also be directly attracting a new type of students to Worcester. Once Worcester is a mecca for high school students all over the country who are dreaming of how to live and work in space, and

Worcester’s high schools themselves are producing more than their share, one is at critical mass to become the place where space oriented businesses want to be as well.

WPI SPACE PROJECTS

Team Dig-It Background

The concept for the first Team Dig-It robot was developed by the team's sponsor, entrepreneur Philip Blackman. Blackman is a graduate of WPI and has worked with students on a similar DARPA challenge before. Blackman designed a concept for the first robot, then asked the students to test the design and revise it to come up with a better concept. His theory was that, in order to beat groups from other prestigious institutions, the WPI team would need to deviate from the common path and come up with a radically different design.

The design initially proposed by Blackman was centered around a rectangular chassis that operated on four wheels. This chassis held a moving table that allowed a sliding plate to be positioned anywhere over the space occupied by the robot. This motion would allow digging in different spots without the entire robot being required to move. This new idea was an attempt to get around the power restrictions, by limiting the robot to either digging motions or movement motions, and preventing both from occurring at the same time.

The actual digging motion of the first robot design was also a departure from common past designs. The design made use of a 'snow blower' concept, churning the regolith with an auger head and throwing it up a tube. This tube would link to another tube which would be running from atop the robot back to the regolith collection bin.

Blackman's intention with this robot design was to make the most efficient use of the power and size restrictions. A combination of slow movement around the competition area, and limited movements at any one time could allow more power to be devoted to a specific movement. Using the rectangular chassis frame the design would maximize digging ability by moving around within the complete area covered by the robot's dimensions. This design, though not intended to be the final iteration, was to be the starting point for an unusual and innovative entry into the 2008 Regolith Digging Challenge on behalf of WPI.

When the team was initially assembled to begin work on this project it was jointly led by sponsor Phil Blackman and a WPI management team as part of an MQP. Motivation quickly waned as team members felt stifled by the imposition of the initial design without a prior brainstorming period to which they could all contribute their ideas. Immediate struggles also arose in that the team could not recruit experienced upperclassmen for the project. Due to previously arranged project assignments, very few seniors had time available to contribute to the project. As a result, the team lacked a depth of experience and leadership. Lots of people were being given jobs they did not know how to do.

After about a month, Blackman returned to his home state of Hawaii. This posed new challenges for the team, especially the student leadership. Although WPI had endorsed the project, it did not commit much by way of resources. Several faculty members agreed to consult, but were not interested in actually putting working time into the development of the robot. In addition, the management team soon decided that project had drifted outside the scope of their MQP. Coupling this with the difficulties of communicating with Phil proved to be too much and the MQP team separated itself from Team Dig-It.

Around this time a junior robotics engineering student volunteered to lead the program. He was immediately disenchanted by what he viewed as micromanagement by Blackman, as well as a lack of discipline and accountability among the other students on the team. This student leader tried diligently to encourage the team towards some measurable progress, but began to feel the same pressure that the MQP team had been under before resigning from the project. The student leader lasted almost two months before deciding he could not work with the project any longer. At this point the team experienced a rude awakening: other teams around the country were reporting significant progress while the WPI team was still in the conception stages. This was due, in part, to the fact that team Dig-It was made up of sophomore and freshman students while the majority of the twenty teams were junior and senior students supported by engineers with years of experience.

At this phase in the project, Blackman embraced Professor John Wilkes' offer to involve a research and development seminar course in evaluating the progress of team Dig-It. Class members were assigned to the various sub-teams in Dig-It and reported back to the whole group with observations and comments. The central theme highlighted by the research and development class was one of limited communication and an unrealistic sense of what could be done with the still untested design in hand.

Some of the key problems were with the initial phase of team Dig-It, which set the team on bad habits. For the most part, the group only got together once a week for a large 'round table' discussion. At any given time there were up to three competing conversations going on, yet most of the people in the room remained unengaged. In addition, meetings usually hosted a few members of the WPI faculty. These professors, while generously giving up their time, were not engaged in the project enough to have a significant impact at the right times. Instead, their input was typically limited to reacting to inefficient or unsafe practices. During these meetings, Phil Blackman would often call or email comments in real-time. He would occasionally also be set up on a webcam so that he could watch the meeting. This caused a strange feeling of disembodied oversight and often slowed the meetings down with extraneous comments or technical difficulties.

One of the last efforts made by the student leader before he departed was to do away with these large meetings and replace them with group time in the laboratory. This attempt did not work because subordinate members of the team decided to override him and changed the meeting time. This obvious lack of regard for leadership was a cause for major concern and was a leading factor in causing a rift between the team and its newest recruit from the R and D class, senior Erik Van Dyke. Erik's past experience led him to form the opinion that the design they were working with, combined with the behavior of the team, would not lead to a successful robot. Erik decided he could not devote himself to the team as it existed and resigned from the project.

At first it seemed as though Erik's separation from the team would cause a problem; however, it turned out to be perfect timing for a paradigm shift in the project. Unbeknownst to the team, Blackman had grown discontented with his own design due to problems that were coming up in testing he was doing on his own. His original plan was to have the students challenge the design he proposed and come up with something better, but this message was never made clear to the students. As a result, Erik's departure became a source of inspiration, and he was asked to form a second team to come up with a competing design.

This alternate design team sought to present a simpler version that was a variant on the idea of making the regolith flow like a thick fluid. In a week's time, Erik's new design went from a rough sketch to a nearly complete design. The original group was asked to consider alternative designs as well. In an effort to spur both teams on and produce some new results, the research and development class, in conjunction with Phil Blackman, the class decided to hold a design review. The design review was held during the research and development class and featured nearly identical presentation templates that each design team filled out. Preparing for this process forced the original design team to actually logically think through their concept, which strengthened the overall process.

When it came time to conduct the design review the results were somewhat surprising. The alternate design presented a unique approach that clearly had a lot of time and effort invested, while the original team did not seem to take the review as seriously and was now proposing something conservative and safe that looked like a dump truck with tracks. . The research and development class found some flaws in the alterative design, which were attributed to a lack of technical expertise. The original design team had a solid presentation, but never intended to follow through with the designs they presented. In the end one design idea for the original team and three to four from the alternative design were identified as the potential core of an innovative a promising synthesis design.

Policy Recommendation

The critical policy question in this case is whether or not WPI can support open forum technical competitions. These challenges come from outside organizations looking to obtain breakthrough design concepts, while education-specific challenges cater more to the learning process. Because these challenges often carry large prizes, the interest comes from many demographics other than students. As in NASA's centennial challenges, often contest teams range from professional engineers to amateur inventors, and the competition is fierce. If WPI wants to continue participating in challenges, some very real consideration needs to be given to the best way to support these initiatives.

Many of these challenges are hosted by high-tech advocacy groups seeking to further knowledge in a particular field. More often than not there is sponsorship from government organizations which would otherwise outsource the concept for research. The concepts are cutting-edge and are generally critical to development in areas like medicine, space, and energy/sustainability. Student participation in these contests allows access to resources and opportunities rarely found in formal education.

While these opportunities are beneficial to students, they place unusual challenges on their sponsoring universities. Schedules of such contests take no consideration of academic term calendars or institution break schedules. Instead, they aim to rapidly develop technology in the most efficient manner possible. Presentation and competition often takes place during the summer, when most students are either working part time jobs or studying in internships. Students also must focus on coursework outside the project, while engineering firms have the luxury of devoting full time employees to research and development. Finally, outside organizations benefit from existing management structure and experience, while student teams struggle with basic organizational tasks before they even consider scientific research and design.

If WPI wants to continue participating in these challenges it needs to provide better support to its student competition teams. Faculty members, used to advising students on projects, will often seek only to serve in a consulting role, rather than actually lending technical expertise to the teams. Encouragement from WPI for faculty to participate fully would help alleviate some of the advantage held by experience competition groups. Groups also need more internal experience and leadership. Student teams are frequently made primarily of underclassmen as upperclassmen tend to focus more on graduation requirements, projects and employment opportunities. By offering course or project credit to these teams, the WPI administration could encourage broader participation, and more dedication from those who choose to become involved. Seniors who participate in successful challenge teams may also find themselves networking with future employers at the associated challenge conferences and competitions. Additionally, contests running outside the normal school year would require special attention from WPI in the form of E-Term (summer) course credit, housing, and financial aid.

In order to motivate these teams properly WPI will require a cultural change. Instead of being viewed as orphan programs, these teams should be sponsored by one or more departments and given the opportunity to represent that department and the school to the world. At the moment there is a de facto gap between project teams and WPI, such that a failure would not necessarily reflect on the institution as a whole. WPI needs to shoulder some responsibility for the output of these teams before it will be able to inspire and motivate students to perform and competitive level.

Many of these challenges are announced and conducted within one year and this short turn-around makes it difficult for WPI students to participate in them for project credit. The project program dictates that most students determine their project, sponsors and advisors many months in advance, which means that by the time interest is growing at WPI for challenges the most skilled and senior students are already occupied with major qualifying projects. The project program could benefit from supporting these challenges, but it needs to become more flexible to allow for short-notice competitions and student recruiting programs. Departmental sponsorship of these teams could also aid in this by suggesting such projects directly to students.

If WPI were to provide more support to its student competition teams it could find its national and global reputation growing. These challenges attract teams from prestigious organizations and are often covered by the news media. In the case of space-related challenges, the teams are producing equipment designs that may actually fly in actual missions. WPI stands to benefit greatly from a reputation in space technology as the space industry is expanding rapidly.

If WPI cannot provide the necessary support to its students then it needs to prohibit participation as official representatives of the school. Failures on the national stage hurt the school's reputation and severely limit the credibility of future teams from WPI. If these competitions are not to be a part of WPI's future then some of the benefits may still be had by participating in similar contests limited to students only. These contests could be used to replace some of the credibility not gained by participating in the open challenges if WPI were to join with other institutions in hosting competitions. This would allow oversight in criteria and curriculum and ensure that such contests would align properly with WPI's goals.

The best option for WPI is to adjust its relationship to competitions and teams. WPI prides itself on producing proficient engineers with real-world knowledge and experience. By limiting students to student-only competitions it would place them in an artificial environment devoid of realistic competition dynamics. In order to prepare them fully for the world of research and development in high-technology, WPI should encourage student participate in open challenges.

CONCLUSION

These three case studies provide insight into the types of scenarios that will help determine the future of space policy. Issues on the national stage are being considered by entrepreneurs and inventors as much as they are by governmental agencies. Technology-oriented academic institutions are training engineers to consider new and interesting problems that will undoubtedly provide the next generation of space travel. Local politics and developments foster an environment that can either encourage or stifle youth interest in these important issues, and will directly influence the popular attitude towards space travel in the coming decades.

These case studies involved different actors on different stages; however, they tie directly to one another. The relationship between students at the elementary and collegiate levels of education cannot be ignored if the youth are expected to follow up on the research being conducted now. Similarly, the reputations and resources of these universities can provide the credibility that otherwise unknown inventors need to product cutting-edge concepts. New businesses stemming from programs like these will eventually feed back into the local economy, allowing for increased youth programs in the field, and more interaction with the universities. These relationships are intertwined, and focus heavily on local goals driven by national needs.

In the next three to five years the aerospace industry will be facing the retirement of 30% of its personnel. This presents a unique opportunity for a paradigm shift as the new generation of space scientists takes over. Taking the space program in a new direction will require new technology that may not be possible to develop in NASA’s existing research and development structure. This new technology will, therefore, need to come from external sources.

Worcester, Massachusetts, has been an industrial and technological leader in the past, and has an opportunity to become a leader in the space industry. Facilitating relationships between the key players at all levels of space technology will allow Worcester to become a critical center for research and learning in space policy and technology. There is no more fitting place for such programs than the home of Dr. Goddard, the father of modern rocketry. By addressing national needs, Worcester will experience opportunities as a city and bring more opportunities in for WPI and other local universities. Delivering the solutions to these issues will allow Worcester to take the national stage as the preeminent city in space development.

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